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FARMER ADJUSTMENTS TO HIGHER ENERGY PRICES

The Case of Pump Irrigators

Melvin D. Skold

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ABSTRACT

Higher energy prices cause farmers using pump irrigation systems to consider several adjustment possibilities. These farmers are not generally able to pass higher energy input costs on to consumers, so higher energy prices will necessarily result in changes in the production process within the firm. These adjustment possibilities include shifting to more energy-efficient crops, reducing the amount of energy used per acre of a given crop, substituting other inputs for energy inputs, or selecting more energy-efficient farming practices and irrigation distribution systems. The potential for each of these possibilities is limited. Increased energy prices pose special challenges for the pump irrigators.

Key words: Pump irrigation, Energy costs, Energy conservation, Energy efficiency, Agricultural adjustments.

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FARMER ADJUSTMENTS TO HIGHER ENERGY PRICES: THE CASE OF PUMP IRRIGATORS

*Melvin D. Skold**

INTRODUCTION

Energy used to pump irrigation water amounts to about 20 percent of all the energy used on farms in the United States. Since 1972 there have been significant price increases in the fuels used to power irrigation pumps. The prices of most petroleum-based fuels almost doubled following the Arab oil embargo of 1973. Natural gas, a common irrigation fuel in the southern Great Plains, has experienced an even greater price increase, and the continued availability of natural gas to irrigators is in question. Prospects are that energy prices will continue to escalate and these price increases will have special impacts on pump irrigators.

This report describes implications of changing energy economics on farmers using pump irrigation systems. It emphasizes the farm firm and the opportunities pump irrigators have for adjustment to changing energy prices. By examining each of the adjustment opportunities in turn, it is possible to gain some insight about the feasibility of each for reducing the impact on farmers of higher energy prices.

There are several adjustment opportunities. Which possibility becomes most important depends on the economic structure of the particular industry and on the physical and biological relationships associated with energy use on pump-irrigated farms. When faced with higher prices for an input such as energy, the adjustment opportunities are to:

1. Pass the higher production costs resulting from increased energy prices on to consumers.
2. Reduce the amounts of energy inputs used by:
    a. Shifting to crops that require less energy to produce or are higher valued relative to energy costs,
    b. Substituting other inputs for the higher priced energy inputs, and/or

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*Melvin D. Skold is an economist with the Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture, stationed at the Department of Economics, Colorado State University, Fort Collins, Colorado.

    c. Reducing the intensity of input use (less energy per acre) while accepting reduced levels of output per acre.
3. Adopt measures to conserve energy while not affecting output levels.
4. Attempt to absorb the added costs of higher energy prices into the firms' production cost structure.

Of course, all of these adjustments may occur simultaneously. Which or what combination of these adjustment opportunities is dominant depends on the situation at hand. Evaluation of each of these possibilities for adjustment to prospective higher energy prices can suggest some conclusions about the effect of energy prices and availability on pump irrigators.

PASSING HIGHER ENERGY PRICES ON TO CONSUMERS

The ability of a firm to pass higher input costs on to consumers depends on the availability of close substitutes for the product.[1] If close substitutes exist, small increases in the price of the products affected by higher energy prices will not be accepted in the market. Rather, consumers will turn to the substitutes that are less affected by the new energy costs. On the other hand, if close substitutes do not exist, producers are more likely to be able to pass increased production costs on to consumers.

Pump irrigation occurs on only about 10 percent of U.S. cropland acreage and this acreage probably produces well over 20 percent of the value of crop output. The increase is not uniformly distributed; well over 80 percent of the pump-irrigated acreage is in the 17 western States (*11*).[2] Thus, pump irrigators contribute only a fraction of aggregate crop output and most of this fraction of output comes from a geographically confined area. The products produced are largely major field crops; the same products are produced by a large number of other producers across the United States.

Under such circumstances, possibilities to pass energy cost increases on to consumers are minimal. Except for a few cases, neither the region nor the pump irrigators enjoy a sufficient share of industry total output to realize these pass-through potentials. As energy price increases force pump irrigation costs higher, the competitive position of pump irrigators relative to other regions, or to suppliers not utilizing this practice, is weakened.

Consequently, given the relatively small market share of pump irrigators and the general lack of differentiation of their commodity outputs from those of other producers, little potential exists to transfer higher energy costs on to consumers. Feed grains produced under pump irrigation will become more costly to produce than feed grains produced under other circumstances. The magnitude of the cost disadvantage to pump irrigators and the pressure to consider other opportunities for adjustment to higher energy prices can be seen by looking at the relative importance of energy-related inputs in the commodity production cost structure under various circumstances.

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[1] The elasticity of demand is also important; generally the products with an inelastic demand do not have close substitutes and an elastic demand is associated with the availability of close substitutes.

[2] Italicized numbers in parentheses refer to references at the end of this report.

REDUCTION IN ENERGY INPUT USE

To consider the various possibilities to reduce the amounts of energy inputs used in pump-irrigated crop production, it is necessary to examine the amounts and forms of energy inputs used under such cropping practices. Further, the impact of higher energy prices on pump irrigation producers is seen by comparing the amounts of energy inputs used under pump-irrigated situations with farming systems which rely on natural precipitation, such as those in western Illinois.

Table 1 presents ERS estimates of corn production costs under 1975 conditions. The different areas were selected from among important corn producing areas to obtain geographic dispersion and representation of different energy sources used to power irrigation pumps (*13*). It is assumed that center pivot sprinkler distribution systems are used in each of the irrigated areas.

Only selected energy-related inputs are explicitly identified. Much of the nitrogen fertilizer used requires natural gas in its manufacture; the cost and availability of nitrogen fertilizer is directly linked to that of natural gas. Many other chemicals used in agriculture are also petrochemically based. Thus, cost itemization for herbicides and insecticides is also shown. The energy relevance of fuel and lubricants for tractors, equipment, and irrigation is obvious.

This accounting is only partial. Energy required in grain drying is not shown. Further, higher energy prices have a recognized inflationary pressure on the cost of most items of production. Increased energy prices make it more costly to produce tractors and other equipment, and farmers' machinery ownership costs are pressured upward. These cost impacts are not evaluated here.

In the pump-irrigated areas, energy-related inputs make up about 55 percent of all variable costs. Energy used directly for powering irrigation pumps varies between 20 and 26 percent of variable costs. In the central Corn Belt, energy-related costs run less than one-half of all variable costs, and irrigation plays no part.

Based on these estimates the effect of, say, a 50-percent increase in the cost of energy-related inputs can be seen. Assuming the same level of application of other inputs per acre, variable costs would increase by $46.37 in Texas, $39.64 in Nebraska, $34.45 in Colorado, and only $21.93 in Illinois. Clearly, the competitive position of the pump-irrigated areas is weakened.

However, it is possible that the per-acre intensity of use of energy-related inputs will change after a significant price increase for these inputs. Also, it is not likely that all energy-related inputs will increase proportionately in price; natural gas and other petroleum-based fuels can be expected to increase in price relative to electricity. Thus, substitutions between energy sources may

Table 1–Cost of producing corn in selected areas with special emphasis on energy-related input costs, 1975

Item	Location							
	Panhandle of Texas		Southwestern Nebraska		Northeastern Colorado		Western Illinois	
	Dollars per acre	*Percent of variable costs*	*Dollars per acre*	*Percent of variable costs*	*Dollars per acre*	*Percent of variable costs*	*Dollars per acre*	*Percent of variable costs*
Nitrogen fertilizer	21.38	12.3	26.88	18.2	26.11	20.3	25.83	25.9
Herbicide	.67	0.4	7.02	4.8	1.72	1.3	9.63	9.7
Insecticide	28.89	16.7	3.72	2.5	3.67	2.9	2.49	2.5
Fuel and lubricants	41.80	24.1	41.66	28.3	37.40	29.2	5.92	5.9
Tractor	4.09		2.08		2.41		3.15	
Equipment	2.41		1.66		1.73		2.77	
Irrigation	35.30	20.3	37.92	25.7	33.26	25.9		
Total energy related	92.74	53.4	79.28	53.9	68.90	53.7	43.87	44.0
All variable costs	173.44		147.08		128.29		99.72	
All operating costs	250.53		223.19		197.18		129.60	
Irrigation fuel source	Natural Gas		Diesel		Electricity		(not irrigated)	
	Bushels							
Yield per acre	124.4		109.0		109.2		116.0	

Source: (*13*).

occur, and producers will cut back on the use of the more expensive inputs by (a) shifting to more water (energy) efficient crops, (b) substituting other inputs for energy-using inputs, and/or (c) reducing the amount of use per acre of the more expensive inputs.

Selecting Energy-Efficient Crops

Water and energy are more or less joint inputs under pump irrigation. To increase water application requires more energy, and reduced water applications will save energy. Crops vary as to their water consumptive use requirements. Variation also occurs between crops as to their response to less water. For example, in western Kansas a 1974 survey showed irrigated corn received 24 acre-inches of water while grain sorghum received 18 inches and wheat only 14 inches (table 2).

As energy (and water) become more expensive, one response might be for farmers to reduce the acreage of irrigated corn and increase the acreage of, say, irrigated wheat. Wheat requires less energy (water) per acre. One can be misled, however, as it is the efficiency of input use, not the amount of input used that is important. A rough measure of input use efficiency is seen by observing in table 2 that the increment in yield over dryland farming is 75.4 bushels for corn, 37.1 bushels for grain sorghum, and 12.8 bushels for wheat. These bushel-per-acre increases translate into value of output per acre increases of \$184.73 for corn, \$84.12 for grain sorghum, and \$43.52 for wheat. Irrigated agriculture also requires increased use of most other inputs; it would be an error to attribute all of the yield increase to water and energy alone. Table 2 also shows the increase in variable costs per acre associated with irrigation.

Using these "average" efficiency measures, it is seen that value of corn output increases about \$7.70 for each acre-inch of water while grain sorghum and wheat increase \$4.67 and \$3.10, respectively.[3] Alternatively, the increase in value of output under irrigation per dollar increase in per acre variable cost is \$2.28, \$1.53, and \$1.05 for corn, sorghum, and wheat respectively. Thus, by both counts—water use efficiency and other input use efficiency—irrigated corn appears to be more efficient in this western Kansas region.

Caution should be given to the interpretation of such data, however. Year-to-year variation in crop response to irrigation and/or changes in commodity prices can easily change the ordering of the crops.

Another problem is the linearity assumption implicit in the "average marginal" measure. For example, grain sorghum has been shown to be highly responsive to preplant irrigation and/or limited postplant irrigations. Consequently, grain sorghum has been touted in several farm magazine articles as being a potential water and energy saver (*9*, *12*). Producers are able to increase

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[3] It is recognized that marginal measures of efficiency are the proper measures for decisionmaking; however, the "average marginal" concept used here is useful for illustration and does provide a rough measure of the relative efficiencies of water and energy use between crops.

Table 2—Response of selected crops to irrigation and other factors, western Kansas, 1975

Item	Corn		Grain sorghum		Winter wheat	
	Irrigated	Dryland[1]	Irrigated	Dryland	Irrigated	Dryland
			Bushels per acre			
Yield	102.7	27.3	66.4	29.3	38.7	25.9
			Dollars per acre			
Value of output (Y)	251.62	66.89	150.73	66.51	131.58	88.06
Variable costs per acre of irrigation (VC)	128.96	47.90	80.42	25.43	65.99	24.59
Change in value of output (ΔY)	184.73	---	84.12	---	43.52	---
Change in variable cost per acre (ΔVC)	81.06	---	54.99	---	41.40	---
			Acre inches			
Water applied per acre (W)	24	---	18	---	14	---
			Dollars per acre			
Value of increased output per inch of water applied ($\Delta Y \div \Delta W$)	7.70	---	4.67	---	3.10	---
Value of increased output per dollar increase in variable costs ($\Delta Y \div \Delta VC$)	2.28	---	1.53	---	1.05	---

[1] Extrapolation of a dryland corn budget from southwestern Nebraska.

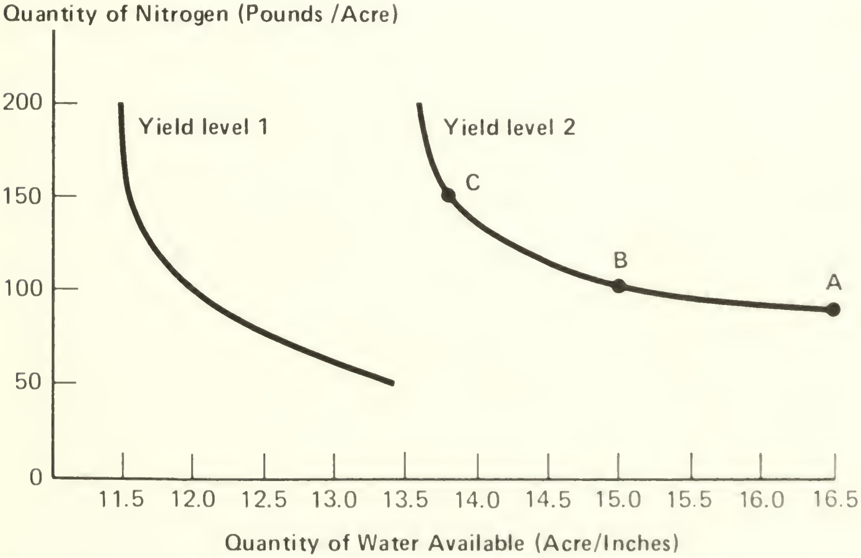
Source: (*13*).

output by allocating water from a well of given capacity over more acres.

Opportunities to increase the efficiency of water (energy) use by allocating less water over more acres is not always possible, however. Surface distribution systems are not completely mobile; hence, water must be spread over adjacent lands owned by the same operator.

Substitution Among Inputs

A second alternative for reducing energy inputs is to substitute other inputs for the energy-related inputs. Production economists refer to this substitution as moving along an isoquant. The concept is illustrated in figure 1. By these data, a certain number of bushels of corn (yield level 1) can be produced with about 13.5 inches of water and 50 pounds of nitrogen, or 12.0 inches of water and 100 pounds of nitrogen, or 11.5 inches of water and 150 pounds of nitrogen. Nitrogen can be substituted for water while maintaining the same level of output per acre.[4] The most desirable (least costly) combination of the water and nitrogen inputs depends upon this rate of substitution and the relative input prices. Assume the least cost combination of inputs at today's prices is at point A, 16.5 inches of water and about 90 pounds of fertilizer. The prices



Source: (5)

Figure 1. Combinations of water and nitrogen necessary to achieve a given level of corn yield, Fort Collins, Colorado, 1968.

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[4] The dominant relationship between water and nitrogen is complementary. That is, increasing water use requires increased use of nitrogen, and vice versa. Thus, the inputs can be considered as substitutes only within narrow ranges.

at point A correspond to a water cost of $1.50 per acre-inch (electricity and repairs cost of pumping 1 acre-inch) and a nitrogen price of about $0.23 per pound. Now, suppose that for some reason the price of nitrogen remains stable but electricity costs increase to $2.25 per acre-inch of pumped water. At these price relationships the least cost combination may shift to point B—about 100 pounds of nitrogen and 15.0 inches of water.[5] Thus, about 10 pounds of nitrogen are substituted for 1.5 inches of water due to a supposed energy price increase. It should be noted that as one moves up a constant yield-level curve as between A and B and on to say, C, it takes increasing amounts of nitrogen to replace an inch of water. With this example, only limited opportunities are indicated to substitute other inputs for water as the price of water increases due to higher energy prices. Since the price of the "substitute" input, nitrogen in this example, is also sensitive to energy price changes, it is likely that increasing energy prices would cause farmers to reduce the use of both inputs. This reduction in intensity of input use is best illustrated for a single input.

Reducing Intensity of Input Use

Holding all other inputs constant, the most profitable level of water application occurs at the point where the value of the additional output per acre-inch of water is equal to the cost of that acre-inch of water. Figure 2 is based on using pump irrigation energy prices and repair costs to represent water costs, and holding the output price constant.[6] This figure illustrates that at low levels of available water, a greater yield response is shown; the 9th inch of available water adds $21.10 to value of output while the 17th inch adds only $1.86 to value of output. These value of output increments per acre-inch of water are the marginal value products of water and they decline at progressively increasing levels of available water. In the example, water application would include at least 17.0 inches of water at today's prices (water pumping costs of $1.50 per acre-inch and a corn price of $2.25 per bushel). Applying the 16th inch adds about $4.50 worth of output, which is more than double the $1.50 pumping cost. The 17th inch adds $2.00 of output which still exceeds the $1.50 pumping cost for the added inch. If the cost of pumping water doubled, it would not pay to apply the 17th inch but the 16th inch would still be profitable.

The nature of the water response function illustrated in figure 2 is such that the value of output added per acre-inch of water is high, even at relatively high rates of water application. With water response characteristics such as those represented here, producers would respond to higher pumping costs by

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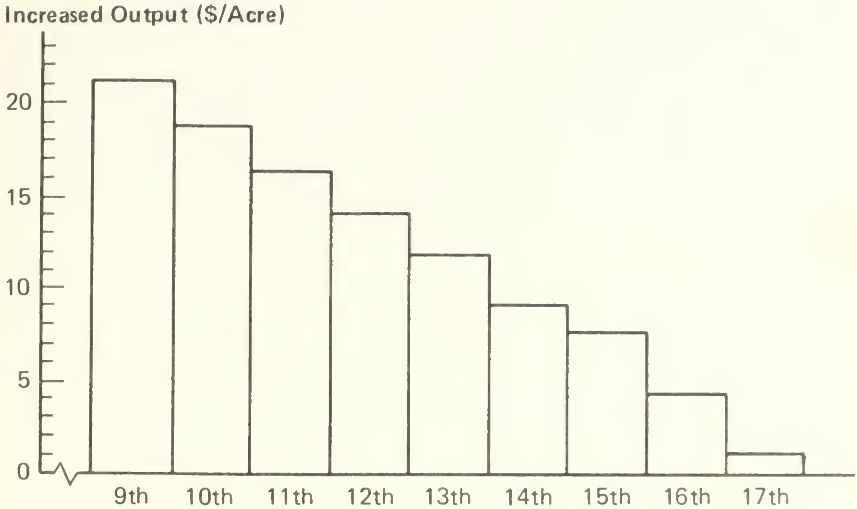
[5] The least cost points A and B are only rough approximations. Economic optima vary not only with the relative input prices but also with prices of these inputs relative to the output price. For a more precise treatment of the substitution process see the original source, (5).

[6] It is recognized here and elsewhere that energy prices and repair costs are not the only variable cost items associated with irrigation water. Depreciation expenses probably also vary with the amount of water applied but they are not considered.



Source: (5)

Figure 2. Additional value of output from increments of water in corn production, Fort Collins, 1968.

reducing the amount of water applied. Not all crop yield-water response relationships are as shown here. It is possible that after applications of the first few inches of water, the added response drops off rapidly. Thus, small changes in water costs may stimulate sizable changes in the amount of water applied. Cursory evaluation of water response functions for other years and locations indicates the same general results (*4*). Producers are allocating water over land so that the value of the marginal inch of water is relatively high. Consequently, the price of the water input can increase a great deal before producers are encouraged to use less water.

CONSERVING ENERGY

Potentials for energy conservation on farms using pump irrigation can be categorized as (1) improving the efficiency of existing water distribution systems, and (2) selecting more energy (water) efficient distribution systems.

Improving Efficiency of Existing Systems

Opportunities are available to achieve increased energy-use efficiency under any given surface distribution system (*2, 6, 7, 11*). Studies have shown that the average efficiency of irrigation engines runs far below potential efficiency levels. A study in Texas, typical of studies of this type, found average efficiency of internal combustion engines to be about 19 percent. Ideally, such engines can operate at 25 percent efficiency; however, a realistic expectation is set at 21 percent efficiency (*2*). The pumps driven by these engines are also less than fully efficient. In the same Texas study, pumps were found to be 52 percent efficient. Again, the theoretical efficiency level is around 72 percent but a realistic level was judged to be 62-percent efficiency (*2*). Certainly, educational programs and economic incentives associated with higher energy prices will do much to encourage increased pump and engine efficiencies.

It has been estimated that a reduction of as much as 25 percent in energy use for pump irrigation in Texas can be attained by increasing pump and power unit efficiencies to realistic levels. To reach this 25-percent saving would require improvements on about 40 percent of the irrigation pumps in the State. The cost of these improvements is estimated to be $116 million. About $53 million worth of energy would be saved using 1974 energy prices (*2*). Given this relationship between cost of improvement and the value of energy saved, indications are that energy prices will have to more than double before economic incentives will encourage substantial pump and power unit efficiency improvements.

Adopting More Efficient Systems

Further potential for energy conservation under pump irrigation systems can be realized by selecting the most energy-efficient distribution systems. A recent study compares the energy efficiency and economic efficiency of seven distribution systems often associated with pump irrigation (*1*). The measure of energy efficiency considers the total energy requirements of each irrigation system including operating, manufacturing, transporting, and installing energy. Ecomomic efficiency assesses the total annual cost of each system including initial investment and annual expenses. Simulation models are used to trace the behavior under each distribution system of kWh per acre and cost per acre at selected field sizes and varied water lift levels.

Generally, as water lift levels change, the various distribution systems—hand move, side roll, solid set, permanent, center pivot, surface, and drip—maintain their same positions relative to each other on both the economic cost and energy design scales. That is, the system which is least costly or most energy-efficient at zero water lift levels remains in its same position relative to other distribution systems as water lift amounts increase up to 1,000 feet. Surface distribution systems are an exception; they are the most energy-efficient at relatively low water lift levels but rapidly lose their efficiency position as the water lift increases. In fact, the surface distribution system becomes less energy-efficient than the center pivot system at water lifts of greater than 250 feet. Surface distribution systems lose their economically efficient position at even lower water lift levels. Thus, systems which rely on gravity to distribute the water can require even more energy per unit of water delivered than systems requiring energy to maintain water pressure.

The simulation results also reveal that energy prices will have to increase a great deal before reinvestment in the most energy-efficient system would occur. In fact, energy prices would have to increase two to three times their existing levels before economic incentives favor such reinvestments. Thus, as with improving pump and power unit efficiencies, shifts to more energy-efficient systems are governed by the necessary investment costs to achieve these energy savings, rather than by the variable costs associated with energy use.

Other Conservation Possibilities

In addition to those discussed above, a few other conservation measures may have some potential for lowering energy costs. Reuse of runoff or tailwater is often advanced as a conservation measure. A few States have required reuse pits for some years; hence, further conservation potentials are limited only to States in which tailwater reuse has not been practiced. Reuse possibilities are generally associated with surface distribution; tailwater accumulates because of the necessity to apply excess water so that adequate water is received on all parts of the irrigated field. Certainly, tailwater reuse is a sound conservation measure which saves both energy and water. It has been estimated that total power consumption can be reduced by 10 to 25 percent under the special circumstances to which tailwater reuse is newly applied.

Installation of automated gated pipe also has the potential for reducing energy use for pump irrigation. Conversion to this system from hand-moved siphon tubes has an estimated prorated annual investment cost of about $560 per 130-acre field (*8*). Repair and maintenance costs are not calculated. Depending on the fuel source, amount of water applied, and the assumed price of fuels, such distribution system conversions can usually be economically justified.

Irrigating only alternate furrows is another conservation technique, but one that can be used only under special circumstances, since the soil type and surface slope make a big difference in the potential of alternate furrow irrigation. In one Nebraska test on a silty clay loam soil, savings of 4 inches of water per acre were achieved, while corn yields per acre were reduced by 9 bushels (*8*). Assuming corn is worth $2.00 per bushel and current water pumping costs prevail (about $1.60 per acre-inch in 1975 see table 1), farmers using this practice would sacrifice about $18.00 per acre in returns to save $6.40 in energy costs. Thus, alternate furrow irrigation is yet to be proven as an energy conservation measure.

Most of the energy conservation techniques discussed here and elsewhere call for additional investment for changes in irrigation systems. The cost structure of irrigation is such that fixed costs tend to dominate variable costs, especially variable energy costs. Thus, while numerous potentials exist to conserve energy, the value of energy saved is often not sufficient to justify additional investments. Energy costs are a significant proportion of total costs, but not sufficient to offset greatly increased investment and nonenergy operating costs.

ABSORBING HIGHER ENERGY COSTS

The above sections have described several opportunities for irrigators to adjust to higher energy costs, but the potentials of each alternative are limited. Consequently, we come to the most unpleasant of the possible adjustments of pump irrigators to rising energy prices—absorbing the higher energy costs into the production cost structure. Economic survival can be sustained only by input use and conservation adjustments; eventually the competitive position of pump irrigators vis-a-vis other producers of common products must be considered. Table 1 indicated the relative importance of energy inputs for pump-irrigated situations and for another agricultural area that did not use pump irrigation. Pump irrigators are more severely affected by rising energy prices than other producers. Returning to the same regions examined in table 1, table 3 illustrates the economic margins between costs and returns; the difference between these measures is the return to land, overhead, risk, and management. Unless adjustments are made, price increases of only about 30 percent for energy-related inputs will wipe out all returns above operating costs for corn production in the Texas and Nebraska regions. A 70-percent increase in energy input prices would remove the operating margin in Colorado but it would take a threefold increase in energy-related input prices to offset the return above operating costs in Illinois. Clearly, pump-irrigated areas are far more vulnerable to energy price increases.

Table 3—Gross returns and operating costs compared to energy-related input costs in corn production, selected regions, 1975

Item	Texas Panhandle	Southwest Nebraska	Northeast Colorado	Eastern Illinois
	Dollars			
Gross returns per acre[1]	279.90	245.25	245.70	261.00
Per acre variable plus ownership costs	250.53	223.19	197.18	129.60
Returns to land, overhead, risk, and management	29.37	22.06	48.52	131.40
Energy-related input costs	92.74	79.28	68.90	43.87
Irrigation pumping costs	35.30	37.92	33.26	---

[1] Assuming a corn price of $2.25 per bushel.

As the returns to land, overhead, management, and risk decline, the values to be imputed to these resources decline. A downward pressure on land values could be expected as the result of higher energy prices. There would also be increased pressure for reduction of management returns in pump-irrigated areas. Eventually, the returns to such resources become so low that their use in the enterprise in question is no longer considered adequate for continued operations.

CONCLUSIONS

Pump irrigators are especially vulnerable to increasing energy prices. Not only are pumping costs a factor but the cost of other energy-related inputs must be considered as well. Because of the nature of agricultural markets, opportunities to pass higher energy costs on to consumers are limited. Similarly, only limited possibilities exist to substitute other inputs for higher priced energy inputs or to improve energy input efficiencies by reduced intensity of use for these inputs. Conservation measures can help to preserve pump-irrigated agriculture, but the cost impacts on pump irrigators are significantly greater than on other producers. Unless alternative energy sources are developed to power irrigation pumps, pump-irrigated agricultural regions will face major economic adjustments.

The dominance of fixed costs in the total cost structure of irrigation is a problem. Higher energy prices stimulate farmers to reduce energy consumed for pumping irrigation water through a variety of means. These adjustments are only partial solutions, however. Eventually the competitive position of irrigated agricultural production will be weakened. Alternative sources of low-cost energy are needed to help preserve the irrigated agricultural economy.

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